



Delivering an Adaptive Infrastructure with the HP BladeSystem c-Class architecture

Technology brief



Abstract.....	2
Introduction: Challenges to the enterprise data center	2
Power, cooling, and density	2
Density	3
Cooling.....	3
Power	3
Complexity and management.....	4
Industry perspective on future data center architectures	5
Foundation requirements.....	5
Dynamic behavior and optimization.....	6
Discovery and state information	6
Managing virtual and physical resources	6
Isolation and encapsulation	6
Analysis and optimization	7
Automation.....	7
Resilience and availability	7
HP Adaptive Infrastructure strategy and portfolio	7
BladeSystem c-Class and Adaptive Infrastructure	8
Standardized IT infrastructure	8
Understanding the Blade c-Class architecture	8
Modularity and scalability	9
Resilience and availability	10
Energy efficiency.....	11
Virtualization	14
Isolation and encapsulation	15
Flex 10 technology	16
Managing virtual and physical resources	16
Management with Insight Dynamics-VSE	17
HP Insight Dynamics – VSE integrates virtual and physical management	17
Continuous optimization with Insight Dynamics – VSE	18
Automation with Insight Dynamics – VSE	18
Implementing an Adaptive Infrastructure with BladeSystem Matrix	21
Conclusion.....	21
For more information.....	22
Call to action	22

Abstract

This technology brief discusses general concepts involved in emerging data center architecture. Some of the challenges that are shaping data centers today include power and cooling, the increased complexity of the infrastructure and how to manage it efficiently, and the total cost of ownership. It is especially critical to manage costs so that operating expenses are reduced. As a result, more resources can be applied to new innovation, driving business growth.

An adaptive, or flexible, infrastructure is required that responds to these challenges. Fundamental requirements for an adaptive infrastructure include modularity, the ability to virtualize systems, manageability, and energy efficiency. More advanced infrastructure functionality requires more dynamic behavior, such as real-time discovery and state information, using the same tools to manage physical and virtualized systems, isolating and encapsulating functions, along with analysis and optimization of computing resources. HP has responded to these challenges with the HP Adaptive Infrastructure strategy and portfolio that delivers a business-ready infrastructure. The BladeSystem c-Class architecture is core to an Adaptive Infrastructure with specific design innovations of modularity, power and cooling densities, improved manageability, and virtualization.

This technology brief focuses on the server technology side of delivering an Adaptive Infrastructure. While storage and networking architectures are important considerations in the Adaptive Infrastructure strategy, they are not the focus of this paper. This brief is written with the assumption that the reader is familiar with HP ProLiant and HP BladeSystem architectures. If not, please refer to the HP websites www.hp.com/go/proliant, and www.hp.com/go/bladeSystem, as well as the additional URLs in the "For More Information" section at the end of this paper.

Introduction: Challenges to the enterprise data center

Much has been written about the challenges to the modern enterprise data center. Some of these challenges are listed and discussed below:

- Power, cooling, and density
- Comprehensive management. Managing a data center is increasingly difficult as a result of the increasing number and complexity of new applications; at the same time, businesses are demanding accelerated deployment of solutions, and the infrastructure continues to get more complex.
- Cost of ownership, including both capital and operational expenses

These challenges will force data center architectures and implementations to move up a level in flexibility and responsiveness to make it a truly business-ready or "Adaptive" infrastructure.

Power, cooling, and density

As aggregate demand for computing cycles has increased, the interlinked issues of power, cooling, and density have emerged as critical issues for enterprise data centers. In some cases, power and cooling costs have emerged as an infrastructure selection criterion that is just as important as performance levels or acquisition cost.

Because of the interdependencies among power, cooling, and density, effective solutions are most likely to come from large integrated system suppliers as opposed to niche market suppliers who typically address only a portion of the problem. The optimal solution will involve understanding workload requirements, technology roadmaps, and facility limitations. It may require a combination of establishing best practices, using efficient components and systems, using virtual machines to consolidate server hardware, replacing servers, building new facilities, optimizing the efficiency of the infrastructure, and outsourcing portions of the enterprise workload.

Density

Density, the amount of throughput that can be provisioned into a given rack footprint, was one of the earliest problems to be recognized. A focus on density in the late 1990's led to the emergence of 1U rack-mount servers such as the HP ProLiant DL360 and DL160 servers. With the recent explosion of Web 2.0, cloud computing, and the general scaling of enterprise requirements, density will remain important. HP continues to improve overall density with BladeSystem servers and specialized scale-out servers. As densities have increased, the focus has shifted to cost efficiency and power and cooling limitations.

Cooling

With increases in server density come cooling problems. As CPU power rose to over 120 watts per socket in the early 2000s, the problem of simply moving the heat out of the chassis and subsequently out of the data center became a serious problem. To understand the magnitude of the problem, consider that by itself, an x86 processor may operate at 120 Watts/square inch; while an electric cooktop element may operate at only 40 Watts/square inch. Designers now face the challenging task of removing this immense heat load from a server which has limited cooling tolerance. At the data center level, administrators need to view the data center holistically: that is, evaluating the energy flow from the computer chip inside a server to the cooling tower of the data center.

Power

While closely linked to density and cooling, the challenges surrounding power also include facility limitations, electricity costs, and overall infrastructure costs. Historically, once a data center reached its available power limit, administrators had to use more efficient equipment, build a new facility, or reclaim resources to optimize the existing facility.

Electricity costs have become a significant portion – as much as 40 percent – of the total data center operating costs. Worldwide, electricity used by servers doubled between 2000 and 2005.¹

Higher rack densities have caused power and cooling costs to surpass the costs of the IT equipment and the facility space. Overall infrastructure costs are increasing as data centers become more mission-critical, requiring additional monitoring and maintenance of redundant power and cooling equipment.² By combining estimates of the annual cost of power with the infrastructure costs, it can be shown that the result leads to a cost more than the server itself (Figure 1).^{3, 4}

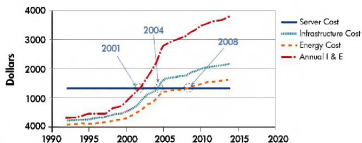
¹ Koomey, J. "Estimating Total Power Consumption by Servers in the U.S. and the World," Stanford University, February 2007.

² The Uptime Institute has introduced a simplified data center Infrastructure Cost equation that sums the costs of raw space with the cost of power and cooling resources. See the technology brief "Data center cooling strategies", <http://h20000.www2.hp.com/bc/docs/support/SupportManual/c01153741/c01153741.pdf> for more details.

³ Belady, C., "In the data center, power and cooling costs more than the IT equipment it supports," Electronics Cooling, volume 13, No. 1, February 2007.

⁴ While energy cost models will fluctuate with the market, the long-term trend for electricity costs is almost certainly up, and prudence dictates that both vendors and users consider this as a permanent state of affairs.

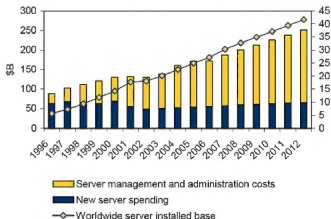
Figure 1. Annual amortized cost of a fully-configured 1U server in a mission-critical (Tier IV) data center



Complexity and management

Increasingly, the greatest ongoing operational cost is the combined management cost associated with servers, storage, and networking hardware (Figure 2).

Figure 2. Cost of server hardware in relation to total management costs



Source: IDC Technical Brief Sponsored by HP, Next-Generation Technology for Virtual I/O and Blade Servers, Doc Number 215119, November 2008

There are several underlying business demands that fuel these management costs:

- Increasing number of applications – competitiveness in business is often tied to bringing new business functions and applications online quickly
- Increasing scale of applications – In both existing web-based enterprise applications and newer Web 2.0 social media applications, applications are being scaled to levels unthinkable a decade ago. Requirements for over 1000 servers in a single procurement for a single application are becoming increasingly common.
- Increasing demands for availability – Almost all customer-facing applications on the web are mission-critical, demanding commensurate availability. In some cases, external regulations for data retention and retrieval on demand are driving availability.

As a result of these business demands, IT administrators are acquiring new server and storage hardware faster than they are retiring it, leading to an increased number of elements to be managed. Routine user operations like moves, adds, configuration changes, patches, updates, and physical maintenance, can become major drains on time and budget.

Industry perspective on future data center architectures

Solving the data center problems described above requires a flexible, business-ready data center architecture. This section uses an industry perspective to discuss two conceptual layers involved in emerging data center architectures: a foundation layer that defines invariant characteristics, and a layer concerned with dynamic behavior and optimization.

Foundation requirements

The foundational requirements define a set of characteristics that are desirable for almost any environment, from small business to the large enterprise:

- Modularity and scalability – The infrastructure must be scalable, capable of providing solutions ranging from a few elements (servers, storage and networking) to large enterprise (thousands of elements), and eventually large cloud-style computing (tens of thousands of elements).
- Energy efficiency – As already discussed, energy efficiency has risen rapidly as a critical technology due to increasing computing demands, increased power densities, facility constraints, and energy cost. Architecturally, energy awareness includes both a system-level and a data center-level component. At the system level, the integrated hardware and software need to use energy-efficient components and take advantage of advanced features to manage power use within systems. At a data center level, administrators should be able to accurately monitor and collect power data, and use advanced control systems along with computation fluid dynamics to optimize infrastructure efficiency.
- Manageability – Since overall management costs are increasingly cited as a primary concern, reducing those costs is a primary goal. Management brings with it the unique challenge of backward compatibility – since most installations of new technology must co-exist with legacy installations, new management architectures and tools must give thought to legacy systems.
- Virtualized and virtualization friendly – Virtualizing server resources along with storage and network elements is one of the major trends of the last half-decade, and a data center architecture must embrace the concept of virtualization of all physical resources.⁵ Support for server virtualization can take many forms, from building servers that efficiently support the latest hypervisors to extending all of the management functions of physical machines to virtual machines,

⁵ While server virtualization is a relatively new phenomenon within industry-standard x86-based servers, the concept of virtualization was developed more than 40 years ago on mainframes and has been implemented in various ways since then.

and vice-versa. Server virtualization in this context refers to the broad set of technologies that abstract an entire physical server and allow its resources to be pooled and shared.

Dynamic behavior and optimization

Customers in large environments of enterprise data centers or hosting providers may need to address the dimension of dynamic behavior. The goal of a dynamic infrastructure includes the ability to change configurations, connections, and functions of infrastructure elements over time. This dynamic behavior could be in response to a single exception condition or planned events such as optimizing for throughput or energy consumption.

The capabilities in this layer typically require more software content than the capabilities in the foundational layer, and require more integration between the disciplines of server, storage, and network engineering/management. Server, storage, and networking hardware should be engineered with the end state of a dynamic infrastructure in mind. The physical elements should increasingly incorporate technologies to facilitate isolation, modularity, and increased resilience where appropriate.

To change configurations and infrastructure elements dynamically, the data center must have capabilities for:

- Collecting discovery and state information
- Managing virtual and physical resources
- Isolating and encapsulating resources
- Analyzing and optimizing resources
- Automation
- Resilience and availability

Discovery and state information

Administrators need to be able to collect information about the infrastructure elements, their state, and their relationships before they can intelligently manage the infrastructure. While much of this information is included within foundational management capabilities, additional information—particularly resource trend information and information about the interrelationships among the elements—is unique to dynamic control behavior.

Managing virtual and physical resources

Historically, virtual and physical resources have been parallel constructs, using different management tools that behave differently and show disjointed views of the data center elements. Converging the behavior and management of virtual and physical resources is critical in implementing a dynamic data center infrastructure. In an ideal world, virtual and physical servers would be viewed as equivalent objects, with identical behavior, as would virtualized storage pools and network resources. Administrators should have design tools that allow a complex infrastructure of virtual and physical devices to be composed into “templates” and then assembled into specific solutions.

While energy-aware optimization for workload placement on both physical and virtual machines is a reality today, work is needed on integrating workload and placement awareness into the entire chain of data center power and cooling operations. This is a longer-term solution that will probably be available within several years.

Isolation and encapsulation

Isolation and encapsulation have been fundamental underpinnings of software architecture for several decades, but remain elusive in the realm of physical infrastructure. An ideal architecture could encapsulate selected regions of the infrastructure so that changes were isolated and encapsulated—essentially masking changes in one domain from the rest of the environment. For example, while

servers, networks, and storage are often separate administrative roles, the elements interact across the data center, which can lead to management complexity. By viewing the infrastructure as a collection of isolated regions, with carefully specified interactions, an architecture that isolates certain regions could potentially reduce management and maintenance costs.

Furthermore, administrators should be able to isolate the design of data center solutions from their deployments. For example, IT specialists could design specific application solutions and then allow other administrators or users to deploy the resources on demand.

Analysis and optimization

The architecture should incorporate data collection and analysis tools to optimize behavior against a number of objective functions, particularly performance (peak performance of an application or throughput in a scale-out environment); and power management (peak capping or average consumption).

Automation

Automation is one of the most overused terms in the industry, with connotations of a technology that magically allows complex systems to respond to changes in their environment, reconfiguring themselves and marshalling resources to meet defined goals and policies. In reality, automation is more like a continuum of technologies that reduces (or eliminates) response time to planned or unplanned events. Automation can be classified according to its overall architecture, its complexity, and its statefulness:

- **Architecture** - automation can be goal-oriented (sometimes called policy-based), or one-to-many push automation. Most common models are one-to-many operations such as: patching and multiple system deployments, cloning to deploy a duplicated resource in a cloud or grid, or moving existing systems in a disaster recovery scenario. One-to-many operations such as volume provisioning and site failover are likely to continue as the most common models for the next two to three years.
- **Complexity** -An automation operation can range in complexity from a single element—such as automatically adjusting the scheduling of a single job or system—to multiple elements of the infrastructure, such as a failover cluster or a Virtual Connect profile migration. At the fringes of current practice is the automation of entire applications or services which span a distributed suite of server, storage, and network resources.
- **Statefulness** - The requirement for detailed state information, particularly for in-process transactions, substantially complicates any automation process. In practice, stateful automation, (primarily failover) is limited to very carefully designed cluster-aware applications or application servers running on tightly-coupled failover clusters.

Resilience and availability

Application availability has traditionally revolved around the twin architectural pillars of failover clustering and the ability to do site disaster recovery. As enterprises move to distributed and scale-out architectures and newer physical and virtual infrastructures, they have new options for high availability and disaster recovery. These new options can range from moving a failed service onto another virtual or physical resource, to wide-area storage replication that can capture and migrate configuration metadata and reconstitute both physical and virtual production resources at a remote site.

HP Adaptive Infrastructure strategy and portfolio

The HP strategy and portfolio for delivering a flexible, business-ready data center architecture is called Adaptive Infrastructure. Adaptive Infrastructure delivers a set of architectural principles that impact data center design and delivers a set of technologies that can be incrementally deployed in existing environments. The ultimate Adaptive Infrastructure is a highly automated environment. It

moves the architecture away from infrastructure silos or "IT islands" to pools of IT resources. These pools allow administrators to realign IT structures to meet specific business goals. An Adaptive Infrastructure environment is based on standard building blocks, automated using modular software, and delivered through comprehensive services. For more details about the HP Adaptive Infrastructure, see www.hp.com/go/ai. Figure 3 represents the key aspects of the HP Adaptive Infrastructure architecture.

Figure 3. Key enablers for HP Adaptive Infrastructure vision



BladeSystem c-Class and Adaptive Infrastructure

The following sections discuss some of the ways that the BladeSystem meets the goals of the Adaptive infrastructure.

Standardized IT infrastructure

The core technologies of the Adaptive Infrastructure are based on cost-efficient, open industry standards. Like all HP ProLiant servers, the BladeSystem c-Class architecture is based on innovation within a framework of industry standards. Furthermore, BladeSystem c-Class architecture was designed as a general-purpose, flexible infrastructure to be extremely modular and scalable. The HP BladeSystem c-Class consolidates power, cooling, connectivity, redundancy, and security into a modular, self-tuning system with intelligence built in.

The following sections outline the general architecture of the BladeSystem c-class and give examples of its modularity, scalability, resiliency, and availability. These are only examples and not an exhaustive list. For more information about current products, see www.hp.com/go/bladeSystem.

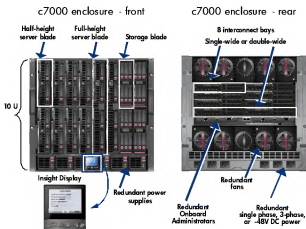
Understanding the Blade c-Class architecture

The BladeSystem consists of several core components (Figure 4):

- The enclosure – An HP BladeSystem c-Class enclosure accommodates server blades, storage blades, I/O option blades, interconnect modules (switches and pass-thru modules), a NonStop passive signal midplane, a passive power backplane, shared power and cooling infrastructure (power supplies and fans), and Onboard Administrator modules for local management.

- **Server blades** – BladeSystem c-Class supports ProLiant server blades using AMD or Intel x86 processors, Integrity IA-64 server blades, and StorageWorks storage blades. The portfolio of server blades range from extreme density-optimized blades to mainstream enterprise blades and specialized offerings for UNIX, small and medium businesses (SMB), and the HP NonStop architecture.
- **Interconnects** – A portfolio of interconnects allow the c-Class blades to interact with external and internal storage and networking. The portfolio includes basic pass-through modules for network and storage, standard managed Ethernet and Fibre Channel switches, and Virtual Connect Modules for Ethernet and Fibre Channel, as well as both standard and specialized NICs for the blades.
- **Virtual Connect** – HP Virtual Connect is a unique HP technology that enables virtualization, isolation, and encapsulation of multiple aspects of server, storage and networks. This is discussed in more detail in the section titled “Virtualization.”

Figure 4. HP BladeSystem c7000 Enclosure as viewed from the front and the rear



Note: this figure shows the single phase enclosure. See the “HP BladeSystem c7000 Enclosure technologies” brief for images of the other enclosure types:

<http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00816246/c00816246.pdf>.

Modularity and scalability

The HP BladeSystem enclosures can accommodate half-height or full-height blades in single- or double-wide form factors, enabling customers to design the infrastructure as their needs dictate. The modular design includes common form factor components so that server blades, interconnects, and fans can be used in any c-Class enclosure, in almost any configuration that customers require.

The architecture uses scalable device bays (for server or storage blades) and interconnect bays (for interconnect modules providing I/O fabric connectivity) so that administrators can scale up or scale out their BladeSystem infrastructure. A single c7000 enclosure contains 16 device bays for server,

storage, or I/O option blades. With the advent of the high-density compute blades such as the ProLiant BL2x220c, up to 32 server blades – each with 2 processors and up to 32 GB of memory for the G5 product – can be housed in a c7000 enclosure.

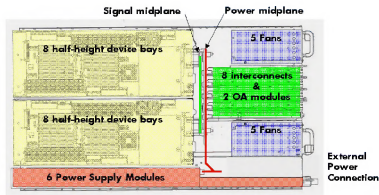
The BladeSystem c-class architecture also provides scalable bandwidth. The NonStop signal midplane is capable of conducting extremely high signal rates of up to 10 Gb/s per lane (that is, per set of four differential transmit/receive traces). For example, in a c7000 enclosure fully configured with 16 half-height server blades, the aggregate bandwidth is up to 5 Terabits/sec across the NonStop signal midplane.⁶ This is bandwidth between the device bays and interconnect bays only. It does not include traffic between interconnect modules or blade-to-blade connections.

Using Virtual Connect Enterprise Manager (VCEM) software, administrators can scale server blade management by pooling multiple enclosures and managing them together. VCEM is a software application that provides management capabilities for up to 150 BladeSystem enclosures. VCEM provides a central console to perform efficient administration of LAN and SAN connections, group-based configuration management, plus the rapid assignment, movement and failover of server-to-network connections and their workloads.

Resilience and availability

BladeSystem c-Class enclosures employ multiple signal paths and redundant hot-pluggable components to provide maximum uptime for components in the enclosure. Independent signal and power backplanes enable scalability, reliability, and flexibility. The NonStop signal midplane and separate power backplane have no active components (Figure 5). Separating the high power delivery in the backplane from the high speed interconnect signals in the midplane results in minimal thermal stress to the signal midplane and high reliability.

Figure 5. HP BladeSystem c7000 Enclosure – side view



The enclosure also houses the Onboard Administrator modules that monitor power and thermal conditions, ensure correct hardware configurations, simplify enclosure setup, and simplify network

⁶ Aggregate backplane bandwidth calculation: 160 Gb/s (half-height server blade) x 16 blades x 2 directions = 5.12 Terabits/s

configuration. A single Onboard Administrator module provides four services for the entire enclosure: discovery, identification, management, and control. An optional second Onboard Administrator in the c7000 enclosure provides complete redundancy for these services.

ProLiant server blades and BladeSystem enclosures include enterprise-class technologies that support reliability, serviceability, and availability:

- Hot-plug disk drives – SAS, SATA, and in the future, solid state drives (SSD)⁷ allow customers to choose the level of flexibility, performance, cost, and availability they need
- Network interconnects – Embedded multifunction Gigabit Ethernet that use TCP/IP offload engine (TOE) technology provide higher availability by offloading TCP/IP network stack processing. HP 10 Gigabit network interconnects that use HP advanced Flex-10 NIC technology can partition the wide pipeline of a 10 Gb connection into four smaller pipelines, enabling redundancy and availability.
- Processor socket technology – The latest Intel AMD processor packages use Land Grid Array (LGA) socket technology to enable higher CPU bus speeds. To prevent damage to the delicate processor socket pins, HP engineers developed a special tool to simplify and ease processor installation.
- Integrated Lights-Out (iLO) management – HP BladeSystem c-Class employs iLO 2 processors to configure, update, and operate individual server blades remotely. The iLO management processor resides on the system board, using auxiliary power and operating independently of the host processor and the OS. Because it is independent of the OS, iLO is fully operational during server blade shut-downs and reboots. It does not depend on the host processor for operation; it is autonomous from the server hardware; and it can perform out-of-band management without any assistance from the OS.
- Multiple I/O connectivity options:
 - Local direct-attached storage devices
 - SAS switches
 - Smart Array controllers that support RAID levels 0, 1, 1+0, 5, 6 with ADG, 50, and 60 with optional Battery-Backed Write Cache (BBWC) for availability

Energy efficiency

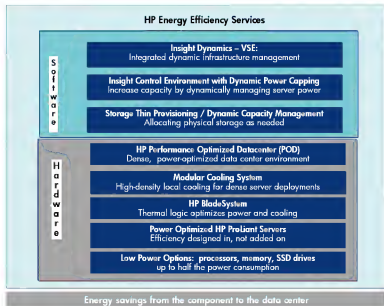
Because of their shared power and cooling, server blades across the industry use less power than their rack-mounted counterparts; and HP has invested significant resources in making the BladeSystem c-Class an exemplar of the savings possible when sharing power and cooling resources.

The efficient BladeSystem c-Class architecture addresses the concern of balancing performance density with the power and cooling capacity of the data center. Thermal Logic technologies—mechanical features and control capabilities throughout the BladeSystem c-Class—enable IT administrators to optimize their power and thermal environment. HP Thermal Logic uses built-in instrumentation, accurate monitoring and control, and the ability to pool, share and allocate power to ensure the amount of power and cooling matches the demand.

⁷ In the first half of 2009, HP expects to introduce hotplug SSDs using standard drive carriers that will be supported across the ProLiant product family.

As discussed previously in the section entitled “Challenges to the enterprise data center,” power and cooling involves a complex chain of small inter-related gains, from the power of individual components to the problems of using data center air chillers efficiently (Figure 6).

Figure 6. Incremental efficiency gains in the IT power and cooling chain



The complexity of this power/heat problem led HP to focus on these aspects of an effective thermal management strategy:

- Accurate measurement of power and cooling resources
- Maximum efficiency
- Real-time analysis and optimization

Table 1 provides some examples of HP technologies that support these design aspects.

Table 1. BladeSystem c-Class thermal-related technologies

Technology	Description	Design Aspects
Active Cool Fans	Active Cool fans use ducted fan technology with a high-performance motor and impeller to deliver high CFM at high pressure. Active Cool fans are controlled by the c-Class Onboard Administrator. The Onboard Administrator can ramp cooling capacity up or down based on system needs. Along with optimizing the airflow, the control algorithm optimizes the acoustic levels and power consumption.	Efficient hardware
Parallel Redundant Scalable Enclosure Cooling design (PARSEC)	In this context, parallel means that fresh, cool air flows over all the blades (in the front of the enclosure) and all the interconnect modules (in the back of the enclosure). The enclosure and the components within it optimize the cooling capacity through unique mechanical designs such as fan louvers, an airtight center plenum, and device bay shutoff doors. Redundant refers to the four cooling zones that provide direct cooling for server blades in their respective zone and redundant cooling for adjacent zones. Scalable refers to the capability to scale the number of Active Cool fans depending on how many and what type of server blades are installed.	Efficient hardware
Instant Thermal Monitoring	If the enclosure's thermal load increases, the Onboard Administrator instructs the fan controllers to increase fan speeds to accommodate the additional demand. It also works in reverse, using all the features of Thermal Logic to keep fan and system power at the lowest level possible. Onboard Administrator monitors the thermal conditions on the hardware in real time, without a delay for a polling cycle.	Accurate measurement Real-time analysis/optimization
Power pooled for N+N power redundancy	All the power in the enclosure is provided as a single pool that any blade can access, providing increased flexibility when configuring the power in the system so that customers can choose the level of redundancy they require. Because this power design has no zones, it facilitates both N+N and N+1 power modes.	Efficient hardware
Dynamic Power Saver Mode (power supplies)	Most power supplies operate more efficiently when heavily loaded and less efficiently when lightly loaded. Dynamic Power Saver mode provides power supply load shifting for maximum efficiency and reliability. Dynamic Power Saver runs the required power supplies at a higher use rate and puts unneeded power supplies in standby mode. When enabled through Onboard Administrator, the total enclosure power consumption is monitored in real time and automatically adjusted with changes in demand.	Efficient hardware Accurate measurement
Power Regulator (processors)	Provides Integrated Lights-Out-controlled speed stepping for x86 processors. The Power Regulator feature improves server energy efficiency by giving CPUs full power for applications when they need it and reducing power when they do not. Allows ProLiant servers with policy-based power management to control processor power states. Power Regulator can be configured for continuous, static low power mode or for Dynamic Power Savings mode. In Dynamic Power Savings mode, Power Regulator determines the amount of time each processor in the system is spending in the operating system's idle loop. It allows the processors to operate in a low power state when high processor performance is not needed and in a high power state when high processor performance is needed.	Real-time analysis/optimization

Technology	Description	Design Aspects
Power capping	Power capping allows administrators to constrain the BTUs per server blade or enclosure, enabling the enclosure to fit in an existing rack power envelope. A simple power cap allows devices to power on until power use reaches the specified power cap and then prevents any more devices from powering on. The optional Enclosure Dynamic Power Capping setting in the OA enables administrators to do power workload balancing and manage power at the enclosure level. As the servers run, the demand for power varies for each server. Dynamic Power Capping constantly monitors power inside the server or blade and then automatically, and nearly instantaneously, adjusts the power draw on the server when it reaches the maximum allocated capacity. This means users can control how much power a particular server blade enclosure is going to use and more accurately allocate that capacity within the datacenter.	Real-time analysis/optimization
Power-aware workload placement	HP Capacity Advisor, part of Insight Dynamics – VSE, allows users to analyze a set of physical or virtual server workloads and recommends optimal placement on underlying physical servers for optimal power consumption.	Real-time analysis/optimization

Virtualization

Having proved themselves reliable, virtual machines (VMs) have become a staple in all modern consolidation and optimization projects. In addition, they allow administrators to isolate and encapsulate an entire OS environment. In fact, the term server virtualization is commonly used as a synonym for virtual machine technology and its software-layer abstraction.⁸

All ProLiant c-Class server blades include the unique Virtual Connect technology that abstracts and partitions the server-to-network I/O connections, and some server blades have been specifically designed for virtual machine deployments with capabilities for large memory footprints, large networking bandwidths, and easily expanded storage capabilities.

Because of their flexibility, BladeSystem servers provide a natural platform for virtual machine implementations:

- Hardware redundancy and availability
- Embedded intelligence with Integrated Lights-Out management and Onboard Administrator
- Capabilities for large memory, processing, and I/O footprints
- Wide range of storage options including boot-from SAN, shared storage, direct-attached hot-plug SAS drives, and Smart Array Controller options
- Power management tools:
 - Power meter for monitoring server power consumption use
 - Power Regulator for higher server efficiency
 - High-efficiency power supplies
 - Dynamic Power capping for provisioning power to groups of ProLiant servers
 - HP Thermal Logic (for monitoring and managing BladeSystem servers)

⁸ Because server virtualization has come to refer to virtual machine technology, HP is moving toward the use of “machine abstraction” and “logical servers” to describe virtualized servers, regardless of whether the virtualization technologies are hardware-based or software-based.

However, server virtualization itself is only part of the solution to current data center limitations, and a modern architecture must also accommodate virtual I/O connections for both network and storage.

Isolation and encapsulation

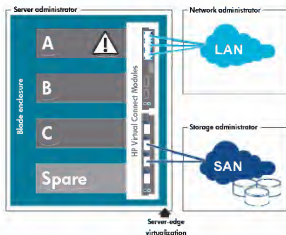
The following are some primary characteristics of I/O virtualization within server architecture:

- Isolating changes to the server network connections
- Compatibility with the external data center networking environment
- Reducing cables without adding any management complexity to the environment

HP Virtual Connect and Virtual Connect Flex-10 technologies meet these requirements. With these HP technologies, businesses can simplify connections to LANs and SANs, consolidate and precisely control their network connections, and enable administrators to add, replace, and recover server resources on-the-fly. As of this writing, Virtual Connect and Flex-10 technologies are available only with the BladeSystem c-Class architecture.

HP Virtual Connect virtualizes the connections between the HP BladeSystem and data center LANs and SANs, allowing administrators to pool and share Ethernet and Fibre Channel connections and make server changes transparent to the networks (Figure 7). Virtual Connect is a physical-layer machine abstraction technology that parallels virtual machine technology (a software-layer abstraction) by allowing similar server workload flexibility and mobility. Just as hypervisor software abstracts physical servers into virtual machines, HP Virtual Connect technology abstracts groups of physical servers within a VC domain into an anonymous physical machine.

Figure 7. Virtual Connect server-to-network virtualization layer



Once the LAN and SAN are connected to the pool of servers, the server administrator uses a Virtual Connect Manager User Interface to create an I/O connection profile for each server. Instead of using the default media access control (MAC) addresses for all network interface controllers (NICs) and

default World Wide Names (WWNs) for all host bus adapters (HBAs), the Virtual Connect Manager creates bay-specific server profiles, assigns unique MAC addresses and WWNs to these profiles, and administers them locally. Virtual Connect securely manages the MACs and WWNs by accessing the physical NICs and HBAs through the enclosure's Onboard Administrator and the iLO interfaces on the individual server blades. It allows these profiles to be modified and migrated without disturbing the data center network administrator's view of the servers – to the external network, a c-Class BladeSystem appears to be a collection of servers with static MAC and WWN assignments.

For more information about Virtual Connect technology, see the technology brief titled "HP Virtual Connect technology implementation for the HP BladeSystem c-Class":
<http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00814156/c00814156.pdf>.

Flex-10 technology

The most recent technology introduced as part of Virtual Connect is Flex-10 technology, which lets customers partition a 10 Gb Ethernet connection and to regulate the size and data speed of each partition. Administrators can configure a single 10 Gb network port to represent up to four physical NIC devices, or FlexNICs, for a total bandwidth of 10 Gbps. Each dual-port Flex-10 device supports up to eight FlexNICs, four on each physical port, and each Flex-10 Interconnect Module can support up to 64 FlexNICs.

These FlexNICs appear to the operating system (OS) as discrete NICs, each with its own driver. While the FlexNICs share the same physical port, traffic flow for each one is isolated with its own MAC address and virtual local area network (VLAN) tags between the FlexNIC and VC Flex-10 interconnect module.

Significant infrastructure savings are also realized since additional server NIC mezzanine cards and associated interconnect modules may not be needed, especially in a virtual machine environment where multiple NICs are needed.

The ability to fine-tune each network connection dynamically from 100 Mb to 10 Gb in 100 Mb increments helps eliminate bottlenecks. Because it has native 10 Gb, administrators can perform ultra-fast virtual server moves and recoveries within a BladeSystem enclosure and between blades; administrators can also precisely control the virtual server network traffic across backup, virtual machine migration, management console, and production application channels.

For more information about Flex-10 technology, see the technology brief "HP Flex-10 technology" at <http://h20000.www2.hp.com/bc/docs/support/SupportManual/c01608922/c01608922.pdf>.

Managing virtual and physical resources

The Virtual Connect solution includes the optional Virtual Connect Enterprise Manager (VCEM) software that provides a central console to manage multiple Virtual Connect domains and efficiently manage LAN and SAN connections across the domain. VCEM allows group-based configuration management. It lets administrators assign, move, and perform failover of server-to-network connections and their workloads for up to 150 BladeSystem enclosures (2400 servers). VCEM provides a central pool of Virtual Connect LAN and SAN addresses, allowing customers to physically or logically link multiple enclosures, and pre-provision the server-to-network connections in bulk.

Virtual Connect also enables the physical layer abstraction of servers in a resource pool, so that administrators can use the concept of a logical server to describe either a virtual machine (virtual machine-logical server, VM-LS) or a physical machine (physical machine-logical servers, PM-LS). HP has developed tools such as HP Insight Dynamics – VSE and HP Insight Orchestration software to manage both virtual and physical machines in a resource pool using the same methods (described in more detail in the following sections). For more information about Virtual Connect Enterprise Manager refer to www.hp.com/go/vcem.

Management with Insight Dynamics-VSE

Embedded management capabilities in the BladeSystem platform and integrated management software streamline operations and increase administrator productivity. Beyond the traditional role of management, one of the key areas in an Adaptive Infrastructure includes virtualized infrastructure management. Contrary to early buildup about virtual machines, they do not simplify the overall environment except for a reduction in physical server inventory. Rather, they introduce a new layer of management for the virtual machines, which has often required a completely separate set of management tools in addition to the standard physical system management tools.

HP Insight Dynamics – VSE integrates virtual and physical management

A major goal of the HP Adaptive Infrastructure has been to integrate virtual and physical server management into a single consistent environment. The first major deliverable of this effort has been Insight Dynamics – VSE, a management suite incorporating virtual and physical management, continuous optimization, and a unified GUI.

At the core of ID-VSE is a virtualization abstraction known as a template. A template is a universal abstraction of a server consisting of the following elements:

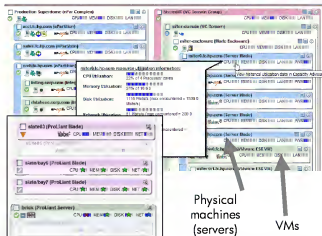
- OS and application stack – The software environment for the server, represented as a link to the boot path for the server. For example, a web server is different from an application server because links are created to two different runtime environments for the same server hardware.
- Runtime entitlements – Description of resources needed at runtime, including memory, number of cores, I/O bandwidth, and so on.
- User-specific data – Administrators must add in specific ID values to convert a template into a specific logical server. For example, to take a “web server” template and convert it into a specific instance of a departmental web server with its own content, administrators need to add user-specific data, such as MAC addresses, WWNs, and global IDs.

A template can be deployed as either a virtual machine or a ProLiant c-Class server blade. Because the physical and virtual servers are generated from a common set of metadata, templates provide the foundation for a new set of merged physical and virtual management capabilities, including transparent P2V and V2P migration⁹ and management integration into a common framework (Figure 8).

Once it is defined, a generic template can be reused for multiple servers and stored in a library of templates. It can also be used as an element in the Insight Orchestration designer tool (see following section) as part of a complex infrastructure.

⁹ The initial release of ID-VSE provides for V2V and P2P migration, but future versions will integrate the V2P and P2V transitions. Currently P2V and V2P are available by means of an escape from the ID-VSE console to the HP Server Migration Pack, a standalone utility for server migration.

Figure 8 Physical and virtual machines shown in the Insight Dynamics- VSE user interface



Continuous optimization with Insight Dynamics – VSE

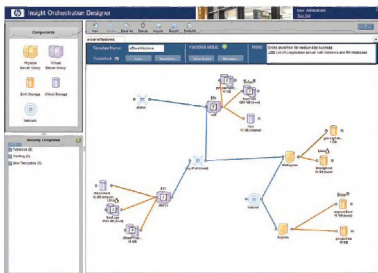
Insight Dynamics – VSE also includes capacity planning technology, providing placement advice for consolidating physical and logical servers based on actual historical performance data rather than models. Administrators can view historical utilization data and pre-test workloads onto different sets of server resources. The placement advice is presented as a rank ordered list of either physical or virtual servers, presented in a convenient one-to-five star rating system with supporting details. The objective function for the optimization algorithm can be either performance or energy consumption, making Insight Dynamics – VSE a powerful tool for maintaining an energy-efficient data center in the face of dynamic workloads.

Automation with Insight Dynamics – VSE

Administrators who are building complex environments can use the optional Insight Orchestration and Insight Recovery functionalities of ID – VSE to streamline their infrastructure deployment.

Insight Orchestration provides a GUI environment to assist in the design of infrastructure templates for applications, which are then stored in a template library (Figure 9). When an instance of the application is required, an authorized user can access a separate self-service provisioning portal for deployment. The HP Insight Orchestration utility allows administrators to integrate logical server planning, design, and provisioning into a unified system. They can create and manage groups of physical and logical servers, and create multi-system templates for server provisioning.

Figure 9. HP Insight Orchestration enables the visual design of standardized infrastructure services.



After the complete infrastructure template has been designed, it can be easily placed into the deployment portal for activation by authorized users (Figure 10). Upon activation, the service is assigned instance-specific information, and the deployment can be connected to a workflow engine to guarantee necessary approvals or to further automate the process.

Figure 10. Self-service deployment portal with “push-button” activation

The screenshot shows the 'Insight Orchestration' console. At the top, there are navigation tabs: 'Overview', 'My Projects', 'My Resource', 'My Queue', and 'My History'. Below these, a sub-header reads 'View and install available templates.' There are icons for 'Go Back', 'New', 'Edit', 'Delete', and 'Create Service'. The main content is a table of templates:

Name	Last Modified Date	Cost	Notes
Blog site	01/09/2019	042.96 USD/Year	Simple blog site suitable for internal communication and information sharing
offering (LAMP) medium (WPB)	01/09/2019	4679.76 USD/Year	Online storefront for medium size business - incomplete. 2018 (LAMP) shared
publicsite	01/09/2019	0.00	
shell	01/09/2019	0.00	
Oracle RAC - Medium Production	01/09/2019	11780.80 USD/Year	Medium throughput configurations for Oracle RAC 12g - 8 Data Node, Production
Windows Database Cluster	01/09/2019	5426.72 USD/Year	Database cluster: Windows internally 2 VMs expandable to 6 VMs

The advantages of separating the infrastructure design and the deployment are significant:

- Clear separation of roles, responsibility, and authorization – By separating roles and privileges between the design and the deployment phases, organizations can follow any desired organizational model for administrators.
- Leverage of high-value architectural talent – Designers are not required to duplicate their efforts for every new deployment of an existing class of service.
- Enforcement of internal standards – Because new service instances are deployed from the templates and are subject to optional embedded workflows for required approvals, internal policies can be rigidly enforced at deployment time.
- Improved quality – Industry experience has shown that standards coupled with a consistent process leads to fewer errors, reduced service interruptions, faster service availability, and lower operational cost.
- Streamlining of application deployment – Early user experience has shown a major reduction in deployment times for complex environments. After the initial time invested in designing templates and workflows, the actual deployments can be done in hours rather than weeks.

Additionally, Insight Recovery allows administrators to configure primary and recovery sites and storage recovery groups for logical servers, allowing automated disaster recovery of logical server environments. With a simple one-button failover, HP Insight Recovery transfers application environments running on HP BladeSystem or in VMware virtual machines to a recovery site, located away from the original site impacted by a disaster. HP Insight Recovery uses the Continuous Access capabilities of HP storage environments to ensure that application data is properly transitioned to the recovery location.

Applications within an HP Insight Recovery environment do not need to be "cluster aware," since the disaster recovery capabilities are handled at the logical server level for physical and virtual environments. This means that any application can take advantage of HP Insight Recovery's benefits within an HP Insight Dynamics – VSE environment.

For more information, see the following websites:

www.hp.com/aa/insightrecovery

www.hp.com/aa/insightorchestration

<http://dacs-internal-pro.houston.hp.com/en/490653-001/490653-001.pdf>

Implementing an Adaptive Infrastructure with BladeSystem Matrix

Implementing and integrating the hardware, software, and management tools needed to enable a flexible environment can be a complex process. To assist with this process, HP is delivering the BladeSystem Matrix: an integrated Adaptive Infrastructure solution that contains the complete management software stack as well as the BladeSystem software. BladeSystem Matrix consists of a combination of elements:

- BladeSystem c-Class infrastructure – A fully configured c7000 enclosure with power supplies, fans, redundant Onboard Administrator, dual Flex-10 Ethernet and dual 8 Gb FC Virtual Connect Modules
- Software – All software and licenses for up to 16 servers for Insight Control Environment, HP Systems Insight Manager, Insight Dynamics-VSE, Insight Orchestration, and VCEM
- Storage – Optional EVA 4400 SAN storage. BladeSystem Matrix will support third-party SANs as well, including onsite integration, but it is the customer's responsibility to configure the LUNs in advance.
- Bundled factory and onsite services for installation, configuration and setup of virtual machines and storage area networks

Customers now have the choice of ordering the individual components of the management stack (Insight Orchestration, ID – VSE, and so on) or ordering the BladeSystem Matrix as a single SKU in a pre-integrated solution. For more information, see the HP website: www.hp.com/go/matrix

Conclusion

IT administrators are stewards of their companies' IT environments. As such, IT administrators must provide increasingly responsive solutions to the data center challenges of today, which include increased power and cooling demands, the need for comprehensive management across the infrastructure, and reduced cost of ownership. The HP Adaptive Infrastructure is our strategy for meeting the data center challenges of today; it includes a portfolio of products that anticipates the required changes of evolving data center architecture. The basic principles are straightforward concepts: standardization, using industry-standard components; virtualization; automation; and technology that support current IT and business practices while allowing future optimization. Because the implementation options can be diverse and complex, HP has the technology expertise and full range of business partnerships to help IT administrators accelerate the planning and deployment of data center solutions based on their requirements and objectives.

For more information

For additional information, refer to the resources listed below.

Resource description	Web address
Adaptive Infrastructure	www.hp.com/go/ai
BladeSystem c-Class	www.hp.com/go/ bladesystem
BladeSystem Matrix	www.hp.com/go/matrix
Industry Standard Servers Technology Communications	www.hp.com/servers/technology
Insight Dynamics - VSE	www.hp.com/go/insightdynamics
Insight Orchestration	www.hp.com/go/insightorchestration
Insight Recovery	www.hp.com/go/insightrecovery
ProLiant servers	www.hp.com/go/proliant
Virtual Connect architecture	www.hp.com/go/ bladesystem/virtualconnect
Virtual Connect Enterprise Manager	www.hp.com/go/vcem

Call to action

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